# An Experimental Study of the Effect of a Six-week Progressive Core Stability Training on Dynamic Balance and Agility in Male Students of Badminton

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***Abstract:*** *To investigate the effects of the 6-weeks progressive core stability training on dynamic balance and agility in male college students specialized in badminton. 65 college students majoring in physical education are randomly divided into an experimental group (for the 6-week progressive core stability training) and a control group (for the 6-week regular physical training). The duration, frequency and intensity of physical training are the same in both groups. The results indicates that after the intervention: (1) The results and overall scores of the 8 directions of SEBT in the experimental group are better than those before the intervention, but there are no differences in the all SEBT results in all directions on the left and right parts. (2) The test results and overall scores of the left leg supported under the experimental group were better than those of the control group in all directions except the results in the anterior and external directions, and the results in the external and anterior directions under the right leg support. (3) Only the reach distance of SEBT under left and right leg support in the control group significantly increases in the external direction compared with that before the intervention. (4) No significant change in agility was observed in both groups. Conclusions: Progressive core stability training can significantly improve the dynamic balance of male college students specialized in badminton among those majoring in physical education, promote the balanced development in dynamic equilibrium on the left and right parts, but it cannot significantly improve their agility.*

***Key words:*** *core stability training; dynamic balance; agility; badminton*



Badminton is one of the most popular racquet sports in the world (Sonoda, Tashiro, Suzuki, Kajiwara, Zeidan, Yokota, Kawagoe, Nakayama, Bito, Shimoura, Tatsumi, Nakai, Nishida, Yoshimi & Aoyama, 2018), and the sport requires quick changes in direction, jump, lunge forward, quick arm moves, maintain a variety of postures, and keep the center of gravity within the point of support (Wong, Ma, Liu, Chung, Bae, Fong, Ganesan & Wang, 2019). Therefore, excellent body balance, especially dynamic balance, is essential for the improvement in badminton skills, sports performance and prevention from sports injuries. Agility is defined as the ability to change speed or direction rapidly in response to stimuli during the whole-body movement (Paul, Gabbett & Nassis, 2016). In badminton tournaments or training, agility is pivotal to either offense or defense and a key variable for excellent badminton performance (Kuo, Tsai, Lin & Wu, 2020).

Dynamic balance and agility are important for badminton sport. But the studies on them are not sufficient (Wong, Ma, Liu, Chung, Bae, Fong, Ganesan & Wang, 2019), The researches on the effects of core stability training on dynamic balance and agility in badminton players are even rarer (Hassan, 2017). No research has been reported on the effects of core stability training on the dynamic balance and agility in college students

specialized in badminton. In order to support the further improvement in badminton teaching effects and the students' skills with data, the effects of 6-week progressive core stability training on the dynamic balance and agility are conducted in male PE students specializing in badminton.

## Subjects and methods

### Subjects

According to the principle of convenience, Tianjin University of Sport was selected as the source for subjects. 35 male volunteers majoring in physical education were recruited for a 6-week progressive core stability training intervention. Thirty-two male students with an average of 1.8-2.0 years under special training were the control group.

Recruitment criteria: (1) free from sports injury or lower extremity osteoarthritic disease, willing to participate in the intense core stability training lasting for 6 weeks, 3 times a week, 20-25 minutes each time; (2) the results of the first test before the intervention supporting their participation in the experiment. (3) Compliance with the experimental design and requirements throughout the experiment. (4) Male students majoring in physical education with badminton specialization and without any experience in core training before this study.

Disqualification criteria: (1) sports injury and suspension of training in the latest month; (2) failure to participate in all experiments and tests due to subjective and objective reasons. Finally, one person quitted the experiment for cold and fever, and another quitted for his sprained ankle when going downstairs. Totally, 65 male PE students specialized in badminton were included. All subjects signed the Informed Consent for The Experiment on The Effect of Core Stability Training on Dynamic Balance and Agility in Males Students Specialized in Badminton before the experiment. The study was approved by the Ethics Committee of Tianjin University of Sport (Grant No. 20200305).

### Methods

#### ***Tests***

The core stability, dynamic balance and agility in all subjects were tested before and after the experiment from May 18 to June 26, 2020. All tests were conducted at the Badminton Hall I, 3rd Floor of the Table Tennis and Badminton Hall of the New Campus of Tianjin University of Sport.

The five indicators of trunk flexion and extension range of motion, dominant side single-leg stance, dominant side single-leg jump, sit-ups, and trunk extensor endurance were used to find out the subjects' core stability (Guo, Li &Wu, 2018). Each subject was tested in all these indexes for 3 times, with a 2-minute interval between every 2 groups. The mean of those three results was quoted in one decimal place.

The star excursion balance test (SEBT) was used for the dynamic balance in the subjects (Hassan, 2017;

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Ozmen & Aydogmus, 2016; Watson, Graning, McPherson, Carter, Edwards, Melcher, & Burgess, 2017). In order for more objective picture of the extension distance in the subject's lower limbs without the interference from the absolute value of leg length, leg length of all subjects was standardized in this study, i.e., the relative distance in each direction (% lower limb length) = the mean value of 3 extensions of the non-supported leg/ leg length ×100 (Gribble & Hertel, 2003). Leg length is measured with a standard tape measure when the subject is lying on the treatment table. It covers the distance from the anterior superior iliac spine to the most prominent bone point on the medial aspect of the ipsilateral calf. The direction of reach was determined by the three measuring tapes attached to the gym floor. Before the test began, the subject stood with his support leg in the center of the grid, which was formed with 8 measure tapes at an angle of 45°between each other. The combined score = the sum of the three means of extensions of the non-supported leg in the 8 directions)/(8 times of the leg length)×100 (Imai, Kaneoka, Okubo & Shiraki, 2014). A total of 3 measurements were taken, with a 2-minute interval between sets. The average of the 3 scores was taken, with the results retained to one decimal place.

The subject's agility was tested in the T-shaped course. The subject ran 10 yards forward to the middle marker as fast as possible from the start, slid 5 yards rightward to the right mark, 10 yards leftwards to the left mark, 5 yards rightward to the middle marker and then run 10 yards backwards to the finish line (Bashir, Nuhmani, Dhall, & Muaidi, 2019). The stopwatch is used to time during the whole course. A total of 3 tests were performed, with 2-minute intervals between each. The average of those 3 test results was taken, with two decimal places retained.

***Experiment***

Pre-experiment. Non- subjects were randomly selected from the PE students specialized in badminton for a pre-experiment on core stability training from April 30th to May 15th, 2020. The exercise load, intensity and difficulty for the official experiment was adjusted according to the results of the pre-experiment.

Official experiment. The 6- week long progressive core stability training was conducted on the experimental group 3 times/week (Tuesday, Thursday, Friday), 20-25 minutes/time from May 18-June 26, 2020. The program consisted of kinetic exercises in steadiness, static exercises and dynamic exercises in unsteadiness. Each of those lasts for 2 weeks. The 6- week conventional physical training was conducted on the control group. The periodicity, frequency and intensity of training were the same as those for the experimental group.

To ensure the quality of experiments and tests, the controls are performed as follows.

(1) Homogeneity in subjects: All subjects were from three parallel PE classes in Tianjin University of Sport. Their courses and daily living habits were almost the same. The pre-test results showed that there was no statistical difference in basic condition, initial core stability, initial dynamic balance, and initial agility between the two groups, which were homogeneous.
(2) High subject compliance: During the experiment, all subjects cooperated at full extent. The training, diet and routine for the both groups were the same, except the core stability training prescribed in this study. The adaptation to core training was low in both groups because there was no specific core training in their daily physical training program. The original physical training content and load were required to be consistent in

the two groups before and after the experiment to exclude the effect from the changes in the physical training program outside the experiment.

(3) Professionalism of experimental and testing personnel: In order to ensure the accuracy and validity of the experiments and tests, senior lab technicians from the university was invited to train the personnel involved in this study. The same professionals served all the pre- and post-tests in the experiment in the same indoor location. The room temperature was controlled at 22~24℃free from any disturbance from the surroundings.

***Statistical analysis***

All data were analyzed by SPSS 26.0. The K-S test was used to test whether the data are normally distributed. If so, the paired t-test was used to analyze the differences within each group, and independent samples t-test was used to for the differences between these two groups. Otherwise, Wilcoxon rank test and Mann-Whitney U test were used, respectively. $P < 0.05$.



# Results

## Subjects' basic information

The basic conditions of all subjects were listed in Table 1. K-S test showed that they were normally distributed.

Table 1

*Basic information of subjects (N=65)*

| Group | Age (y) | Height (cm) | Body weight (kg) | Campaign years (y) | Lower limb length (cm) |
|---|---|---|---|---|---|
| Experimental group (N=33) | 20.9±1.4 | 174.1±4.8 | 68.9±9.6 | 1.9±0.2 | 87.4±2.5 |
| Control group (N=32) | 19.9±0.8 | 176.2±3.7 | 69.1±4.3 | 1.8±0.1 | 88.9±1.9 |

*Group E: Experimental group; Group C: Control group.*
*Compared with pre-experiment, *$P<0.05$, **$P<0.01$; compared with the control group, #$P<0.05$, ##$P<0.01$.*

The independent samples t-test showed that there was no statistical difference between the two groups of subjects in all basic conditions (all P values > 0.05).

## Comparison between the subjects’ core stability before and after the intervention

Guo Liang claims the components of core stability are in five dimensions, namely, core strength, core endurance, core flexibility, core control, and core functionality (Guo, Li & Wu, 2018). In this study, the evaluation indexes for core stability were designed for expert interviews accordingly. The results reveals that the five indicators of trunk flexion and extension range of motion, dominant-side single-leg stance, dominant-side single-leg jump, sit-ups, and trunk extensor endurance are representative indicators for the five dimensions

above. With those five indices, the subjects were tested in their core stability.

The K-S test showed that the data of all subjects' core stability in pre-test are normally distributed. The independent samples t-test showed that before the intervention, there was no significant difference between the two groups in the five tested indexes (all P values > 0.05) (Table 2). It suggests that before the experiment, the core stability level of the subjects in the two groups was homogeneous.

Table 2

*Comparison of core stability-related test indicators between the two groups of subjects before and after the intervention (N=65)*

| Group | Indicators | TFE(cm) | DLS(s) | DLH(cm) | SU(times/min) | EE(s) |
|---|---|---|---|---|---|---|
| Experimental group (N = 33) | Pre-experiment | 10.5±3.0 | 19.9±9.0 | 195.5±7.5 | 46.1±8.0 | 78.4±9.2 |
| | Post-experiment | $14.1\pm2.^{7\#**}$ | $41.3\pm4.^{4\#**}$ | $208.3\pm4.^{8\#**}$ | $51.5\pm2.^{9\#\#*}$ | $94.0\pm3.^{9\#\#*}$ |
| Control group (N = 32) | Pre-experiment | 9.8±3.9 | 22.5±9.2 | 191.0±9.1 | 47.0±7.3 | 83.4±13.2 |
| | Post-experiment | 9.2±5.8 | $35.3\pm5.^{8*}$ | $199.4\pm3.^{7*}$ | 45.7±3.6 | 83.9±8.8 |

*TEE: trunk flexion and extension range of motion; DLS: dominant side single-leg stance; DLH: dominant side single-leg jump; SU: sit-up.*
*EE: Trunk extensor endurance.*
*Compared with itself, *P<0.05, **P<0.01; compared with the control group, #P<0.05 and ##P<0.01.*

The results of the K-S test also indicated that the five post-test indicators for the subjects' core stability were normally distributed. Independent samples t-test was used to compare the differences in the five post-test indicators of intervention between the two groups of subjects. The results showed that all five test indicators in the experimental group were higher than those in the control group (all P values < 0.05), especially, the sit-ups and trunk extensor endurance indexes (all P values < 0.01) (Table 2).

Paired-samples t-test was used to examine the core stability data of the experimental group before and after the intervention. Significant improvements in the five core stability data were found in the experimental group after the intervention (all P-values < 0.05). Among them, the most significant ones are trunk flexion and extension range of motion, dominant side single-leg stance, and dominant side single-leg long jump (all P values < 0.01).

Paired t-tests revealed that there was a significant improvement in dominant-side single-leg stand (P< 0.05) and dominant-side single-leg jump (P< 0.05) in the control group after the intervention, and there were no statistical differences in the changes of other indicators (all P values > 0.05) (Table 2).

## Comparison between the subjects' dynamic balance ability before and after intervention

After reviewing the literature and interviewing experts, the star excursion balance test (SEBT) was taken as the evaluation index for dynamic balance ability in this study.

The K-S test proved that all the pre-test indicators in the subjects' star deflection balance test are normally distributed. An independent samples t-test was conducted for the SEBT results of the subjects in the two

groups before the experiment revealed that there was no significant difference between the test results of the two groups in the eight directions and the overall performance under left and right leg support (all P values > 0.05) (Table 3).

Table 3

*Comparison of SEBT test results between the two groups of subjects before and after the intervention (N=65) [% lower limb length]*

| Support leg | Indicators | Experimental group (N = 33) | | Control group (N = 32) | |
|---|---|---|---|---|---|
| | | Pre-experiment | Post-experiment | Pre-experiment | Post-experiment |
| left Legs support brace | Front | 84.5±7.2 | 97.8±6.$^{3££}$ | 85.4±7.6 | 86.4±4.9 |
| | Outside front | 73.2±7.8 | 87.4±5.$^{3\#\#££}$ | 75.2±8.8 | 77.4±6.6 |
| | Outside | 66.3±14.1 | 81.9±8.$^{1£}$ | 68.0±12.8 | 77.6±8.$^{7£}$ |
| | Outside Back | 82.9±13.7 | 97.1±6.$^{6\#££}$ | 76.5±13.1 | 83.9±5.3 |
| | Back | 90.3±14.1 | 101.1±7.$^{8\#£}$ | 89.5±12.8 | 92.9±9.2 |
| | Inside Back | 83.5±13.2 | 103.3±8.$^{3\#£}$ | 88.7±12.8 | 90.2±9.5 |
| | Inside | 90.8±11.8 | 99.1±6.$^{5\#£}$ | 87.9±10.8 | 89.3±7.6 |
| | Inside the front | 90.8±9.0 | 97.6±3.$^{3\#£}$ | 90.3±8.3 | 91.9±3.1 |
| | Comprehensive | 84.1±11.1 | 93.8±6.$^{2\#££}$ | 83.7±10.8 | 84.3±6.6 |
| Right Legs support brace | Front | 84.1±6.8 | 96.2±5.$^{8\#££}$ | 85.0±7.6 | 91.2±5.$^{8*}$ |
| | Outside front | 79.4±9.$^{0**}$ | 86.2±3.$^{1\#\#£}$ | 81.7±10.$^{3**}$ | 82.1±3.$^{8*}$ |
| | Outside | 65.6±13.1 | 81.1±9.$^{1££}$ | 66.5±14.2 | 81.2±7.$^{5£}$ |
| | Outside Back | 81.7±14.6 | 96.2±5.$^{2\#\#££}$ | 82.3±13.$^{5*}$ | 83.1±5.3 |
| | Back | 90.1±12.8 | 99.5±5.$^{2\#££}$ | 88.8±14.1 | 91.7±4.8 |
| | Inside Back | 90.2±14.$^{0*}$ | 102.5±5.$^{1\#\#££}$ | 89.9±13.9 | 91.7±4.2 |
| | Inside | 90.2±13.5 | 99.4±5.$^{5\#££}$ | 89.7±12.7 | 94.5±3.$^{1*}$ |
| | Inside the front | 90.1±9.3 | 96.7±3.$^{9£}$ | 89.6±9.6 | 90.8±6.2 |
| | Comprehensive | 83.8±11.2 | 93.4±5.$^{1\#££}$ | 83.7±12.0 | 85.1±4.8 |

**P<0.05, **P<0.01 compared to own left leg during the same period; $^{\#}$P<0.05, $^{\#\#}$P<0.01 compared to control group.*
*$^{£}$P<0.05, $^{££}$P<0.01 compared to own ipsilateral before the experiment.*

Before the intervention, the intra-group differences in the SEBT results under the left and right support legs were compared. It showed that the reach distance (% lower limb length) under the right leg support in the external anterior direction was significantly higher than that under the left leg support in both groups (both P values < 0.01), and the reach distance (% lower limb length) under the right leg support in the external posterior direction in the control group and in the internal posterior direction under the right leg support in the experimental group significantly exceeded the reach distance under his own left leg support (all P values < 0.05).

After the intervention, the standardized values of SEBT post-test indicators in both groups of subjects are normally distributed. The independent samples t-test result showed that the experimental group's standardized values under the left leg support were better than those of the control group in all six directions and in the overall performance (P value < 0.05), except the standardized values in the anterior and lateral directions, which were not statistically different from each other (P value > 0.05). The distance in the external anterior direction (% lower limb length) was significantly farther than that of the control group (P<0.01). With the right leg support, the experimental group outperformed the control group in all six directions and overall performance (P value < 0.05), except the standard values in the lateral and medial-anterior directions, which were not statistically different from the control group (all P values > 0.05). The reach distances (% lower limb length) in the external anterior, external posterior and internal posterior directions were significantly higher than those in the control group (all P values < 0.01) (Table 3). Although some of the SEBT post-test results

were not statistically different between the two groups of subjects, the overall test results of the experimental group were better than those of the control group.

After the intervention, the intra-group differences in SEBT test results between the two groups of subjects under left and right leg support were compared again. It was found that the reach distances in the anterior, external anterior, internal directions were significantly higher in the control group under right leg support than under left leg support (all P values < 0.05), while the scores in all directions and the overall scores in the SEBT test under left and right leg support in the experimental group were close and all statistically different (all P values > 0.05).

Paired-samples t-test was used to compare the SEBT data before and after the experiment in the control group. It was found that after the 6- week conventional physical training, only the reach distance in the external direction under the support of the left and right legs increased significantly in the control group compared with that before the intervention (all P values < 0.05). The rest of the directions and the overall performance showed a small increase but no significant change (all P values > 0.05).

Similarly, the core stability data of the experimental group before and after the experiment were tested with paired-sample t-test. The results showed that after the 6-week core stability training intervention, the experimental group's performance with the left and right legs supported under each direction and overall performance were significantly better than those before. Among them, the anterior, external anterior, external posterior directions and overall performance under left leg support and the anterior, external, external posterior, posterior, internal posterior, internal directions and overall performance under right leg support were significantly improved (all P values < 0.01).

## Comparison between subjects' sensitivity before and after the intervention

Table 4

*Comparison of T-test results between the two groups of subjects before and after the intervention (N=65)*

| Indicators | Experimental group (N = 33) | | Control group (N = 32) | |
|---|---|---|---|---|
| | Pre-experiment | Post-experiment | Pre-experiment | Post-experiment |
| T-test | 10.07±1.29 | 9.98±1.33 | 10.13±1.17 | 10.09±1.24 |

*Compared with pre-experimental, *P<0.05, **P<0.01; compared with control, #P<0.05, ##P<0.01.*

Based on the review of literature and interviews with experts, T-shaped test was taken as the evaluation index of sensitivity to badminton items. The K-S test proved that the subjects' performance in indexes before the test were in normal distribution. Independent samples t-test was conducted on the pre-test results of the two groups of subjects. It was found that there was no statistical difference in the T-shaped test results between the groups (all P values > 0.05). Similarly, no statistical difference was found between the groups for the post-test results (p-values > 0.05) (Table 4).

## Discussion

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Core stability has proven to be essential in many sports. The core stability training has become an integral and important part of modern physical training. There are many different methods of core stability training. For example, Hoppes' 8-week core stability training with subjects included static, dynamic, and kinesthetic training methods in steady state (Hoppes, Sperier, Hopkins, et al, 2016); Hongju et al. used unstable planes for core stability training with subjects, such as the Swiss ball (Liu, Li, Du, et al, 2019). The results of all of these studies showed that core stability was improved after 8–12-week core stability training. Accordingly, static, dynamic and combined kinetic training methods were used in the first phase of the study or steady state. In the second and third phases, the unstable apparatus, the Swiss ball, were used for progressive core stability training to increase the difficulty and load of the exercises for the experimental group.

To the authors' knowledge, it is the first study to examine the effects of core stability training on dynamic balance and agility in male college badminton specialists. The results showed that the 6-week progressive core stability training resulted in significant improvements in core stability and dynamic balance, but had little effect on agility compared to conventional physical training.

Compared to similar studies (Ozmen, Aydogmus, 2016;Olmsted, Carcia, Hertel, et al, 2002;Imai, Kaneoka, Okubo, et al, 2014), the study had the shortest duration, fewest devices. The Swiss ball was only used in the second and third phases, but the improvement in the subjects' dynamic balance was significant and resulted in more balanced dynamic equilibrium with left and right foot support.

## The effect of core stability training on the dynamic balance of badminton special boys

The control of body balance is an integrated process of neuromuscular activity, where the organism mainly relies on the nerve impulses sent by the vestibular organs, visual and proprioceptive systems in response to stimuli and their integration of information, accompanied by the synergistic action of the various muscle functions, which ultimately leads to the effective control of motor effectors (Jadczak, Grygorowicz, Wieczorek, et al, 2019). In terms of nature, equilibrium can be divided into static and dynamic equilibrium. Dynamic equilibrium is more important in the motor process since it is less likely for the organism to be static but more likely to be dynamically balanced during movement (Guzmán-Muñoz, Valdes, Méndez-Rebolledo, et al, 2019).

Dynamic balance is one of the most important motor skills and is considered to be the ability to maintain or regain a stable position when performing a given movement (Maszczyk, Gołaś, Pietraszewski, et al, 2018), or the ability to maintain or regain balance on an unstable surface with minimal external motion (Szafraniec, Chromik, Poborska, et al, 2018). For most sports, improvement in dynamic balance is helpful to improve the overall athletic performance (Rafał, Janusz, Adam, 2020).

Badminton is a sport requiring skills and involving confrontations over net. Although there is no direct physical contact in the sport, good dynamic balance is essential in badminton. The constant changes between attack and defense, and in rhythm require the changes and maintenance in body posture in a series of movements such as rapid change of direction, jumping, forward lunge, and rapid arm swing (Towel, Ada, Karen, et al,

2019).

On the basis of special characteristics of badminton and the results of expert interviews, star offset balance was selected as the evaluation index for dynamic balance ability in badminton events in this study (Olmsted, Carcia, Hertel, et al, 2002). After a 6-week core stability training for the experimental group, it was found that the test results and overall scores of all directions in the SEBT test under the left and right support legs of the experimental group were significantly higher than those before the intervention. In particular, the test results and comprehensive scores in the anterior, external anterior and external posterior directions under the left leg support and the test results and comprehensive scores in the external direction under the right leg support were significantly higher. In addition to this, the results and comprehensive scores of the experimental group in the direction under the left leg support in the anterior and lateral, and the right leg support in the lateral and medial-anterior directions were significantly increased compared with those before the intervention, except the left leg support in the anterior and lateral, and the right leg support in the lateral and medial-anterior directions, which did not have significant changes. The test results of some directions were significantly higher than those of the control group, although there is no significant change in those before the intervention. This is similar to the results in Olmste's study (2002).

Sandrey noted that a 6-week core stabilization training intervention (30 min × three times per week) significantly enhanced dynamic balance in high school track and field athletes. The reason for this may be that the agility and strength of the hip and thigh muscles that move the limb in the direction of the target affects reach when participants stand on one foot during SEBT (Guo, Li & Wu, 2018). Similar results were obtained in high school soccer players after a 12-week core stability training (3 times per week) (Imai, Kaneoka, Okubo & Shiraki, 2014). Granacher compared the effects of core stability training on stable and unstable surfaces. In particular, after 6-week core stability training on an unstable surface, 27 adolescents showed a 2-3% improvement in balance (Watson, Graning, McPherson & et al, 2017). Similarly, dynamic balance was improved in badminton players after an 8-week of core stability training (Hassan, 2017; Guo, Li & Wu, 2018). A 9-week core stability training program (30 minutes × 3 times per week) improved the dynamic balance of college competitive dancers (Ozmen & Aydogmus, 2016). In this study, the gradual implementation of progressive core stability training on static stable surface-dynamic stable surface-dynamic unstable surface significantly improves the subjects' reach distance and overall performance in different directions of SEBT. Meanwhile, after the 6 -week of core stability training intervention, the SEBT imbalance under left and right leg support before the experiment disappeared. In conclusion, compared with conventional physical training, core stability training helps to improve the dynamic balance level and left-right balance development in male badminton specialists. Core stability mainly includes passive subsystem, active subsystem, and neural control subsystem. The mutual compensation of the three subsystems in function provides the relative stability of the body core (Katarzyna & George, 2021).

### Changes in subjects' sensitivity before and after the experiment

It is well known that badminton requires much agility in the body. When the upper and lower limbs move rapidly in different directions, strong core muscle strength is required. Some scholars believe that core stability training can improve the agility in subjects. For example, Syed found that after a 5-week core stability training in 30 junior tennis players, dynamic balance and agility were improved in the experimental group

compared to the control group (Watson, Graning, McPherson & et al, 2017). However, more literature confirms that the effect of core stability training on agility is not significant. The present study experimentally confirmed that the 6-week progressive core stability training did not significantly improve the agility in male PE students specialized in badminton.

Nesser et al. did not find a significant relationship between core stability and agility or sprinting (Nesser & Lee, 2009). He suggested that strong core muscles may provide support to the lower extremities during agility tests, but that explosive exercises for the lower extremities may be more effective in developing agility. Therefore, this may be the reason why the participants' agility did not significantly improve after 6 weeks of core stability training.

Schilling's study showed that core stability training twice a week for 6 weeks resulted in significant improvements in dorsiflexor endurance, flexor endurance, and lateral recumbent endurance in 10 untrained college students. However, their agility, sprinting and vertical jumping abilities did not improve (Schilling, Murphy, Bonney & Thich, 2013). The reason for this may be that core stability training is not the only contributing factor to these qualities. Therefore, it is recommended that strength training be added to agility exercises and that a longer training program may be required to see significant improvements in agility.

This study experimentally confirmed the effects of the 6-week progressive core stability training on dynamic balance and agility in male college PE students specialized in badminton, providing an evidence base for targeted instruction and motor skill improvement. There are some shortcomings in this study. Firstly, although lower limb kinematics may affect dynamic balance, this this confounding factor is not taken into consideration when the data is analyzed. Second, the results of this study were obtained with a sample of male college students majoring in physical education with badminton specialization, it is not appropriate to generalize it and apply it to badminton players at other training levels.

## Conclusion

(1) Progressive core stability training helps to improve core stability and dynamic balance significantly, and is beneficial to the balanced development in dynamic balance capacity of the left and right parts of the organism. This is related to the mutual compensatory effect of the three subsystems in function.

(2) Progressive core stability training did not significantly improve agility in the subjects. Explosive exercises for the lower extremities may be more effective in developing agility, or longer core stability training may be required before the significant improvements in agility are visible.

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